

MiniBooNE: Status and Plans

URA Visiting Committee
Friday 12th March, 2004

- Motivation
- MiniBooNE Overview
- Current Status
- Conclusions

Chris Green 
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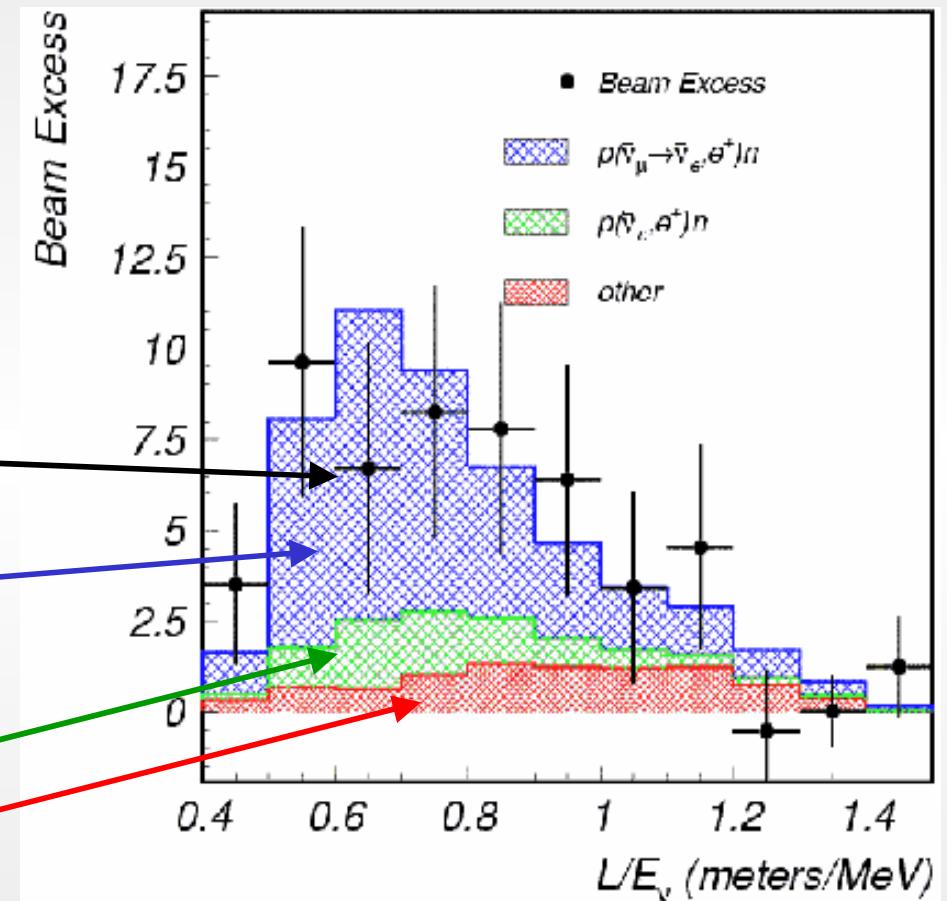
Oscillations and LSND

- Signal over background:
 $87.9 \pm 22.4 \pm 6.0$ events
- Oscillation probability:
 $(0.264 \pm 0.067 \pm 0.045) \%$
- 3.8σ result!

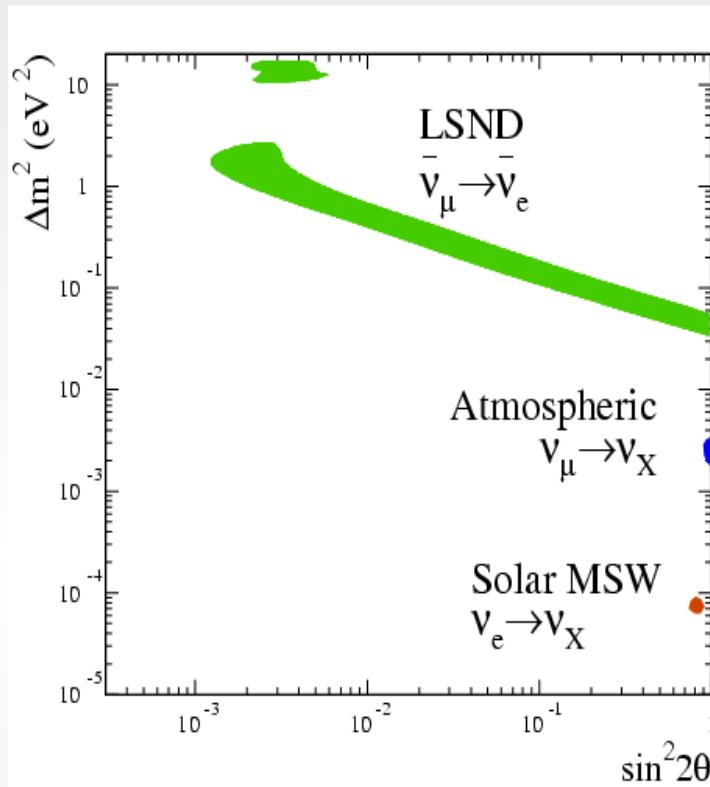
Data points
after beam-off
subtraction

Expectation
for oscillation

Beam related
backgrounds

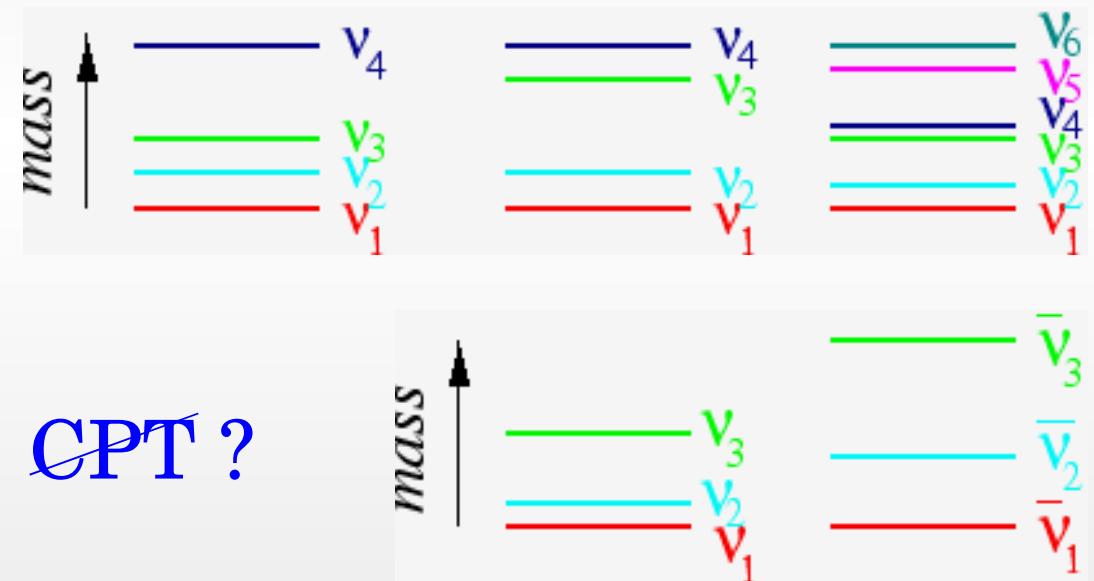


New physics at FNAL?



3 distinct Δm^2 regions: no explanation with 3 standard neutrinos.

Sterile?

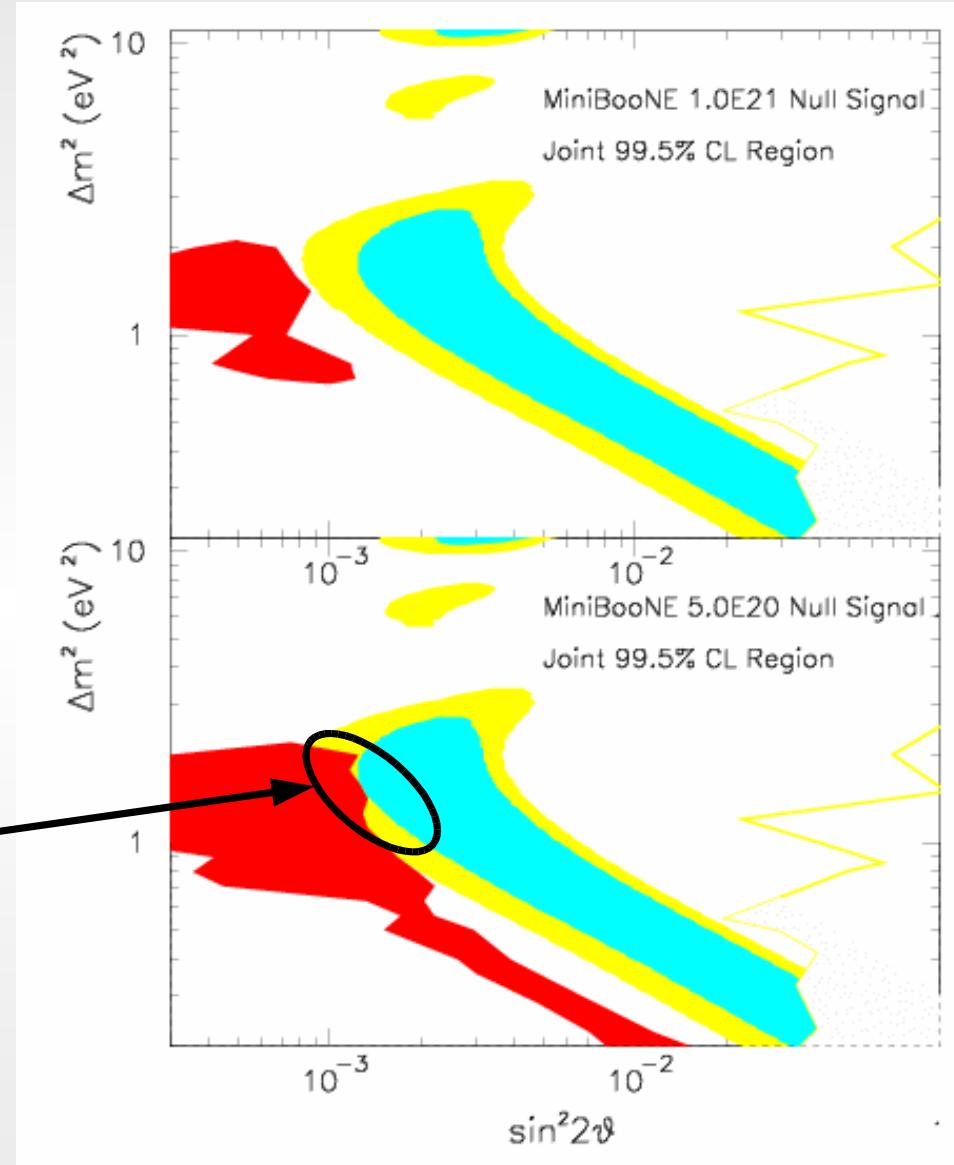


(Barenboim *et al.* (*Phys.Lett.B534:106.2002*))

Enter MiniBooNE

- Same L/E
- Different systematics
- Measure ν_μ disappearance and ν_e appearance
- Smaller duty cycle \Rightarrow lower cosmic ray background

Can rule out LSND conclusively with 1×10^{21} POT, but need $1 \times 10^{21}!$



The MiniBooNE Collaboration

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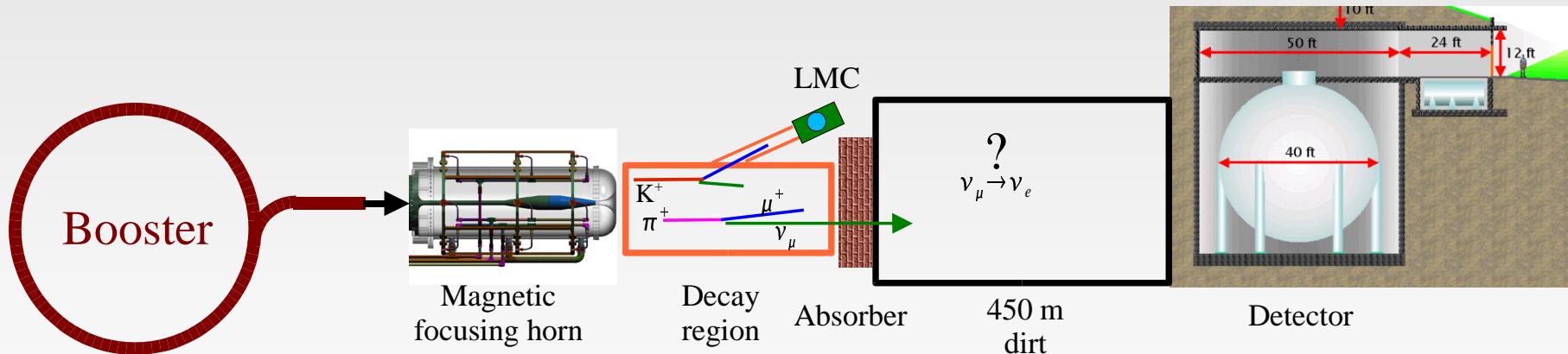
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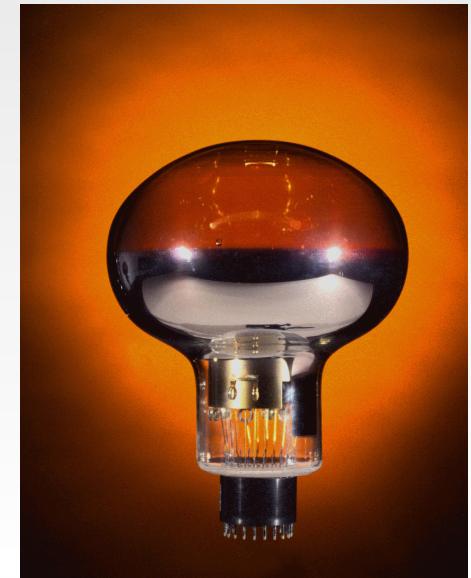
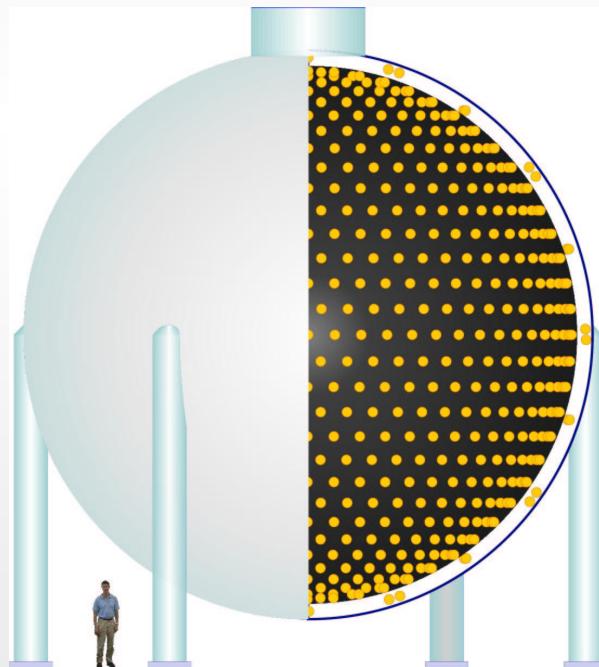
The MiniBooNE beamline



- 8 GeV protons from FNAL Booster strike beryllium target: world's highest intensity ν beamline!
- Magnetic horn to focus decay products: design lifetime $\sim 200M$ pulses at 5Hz average rate ($>56+10M$ so far)
- Monitoring systems for primary & secondary beams
- Little Muon Counter helps measure ν_e background from kaons (7° to beam direction).

The MiniBooNE Detector

- 12m diameter sphere
- 250,000 gallons of white mineral oil
- Optically isolated inner region with 1280 PMTs (10% coverage)

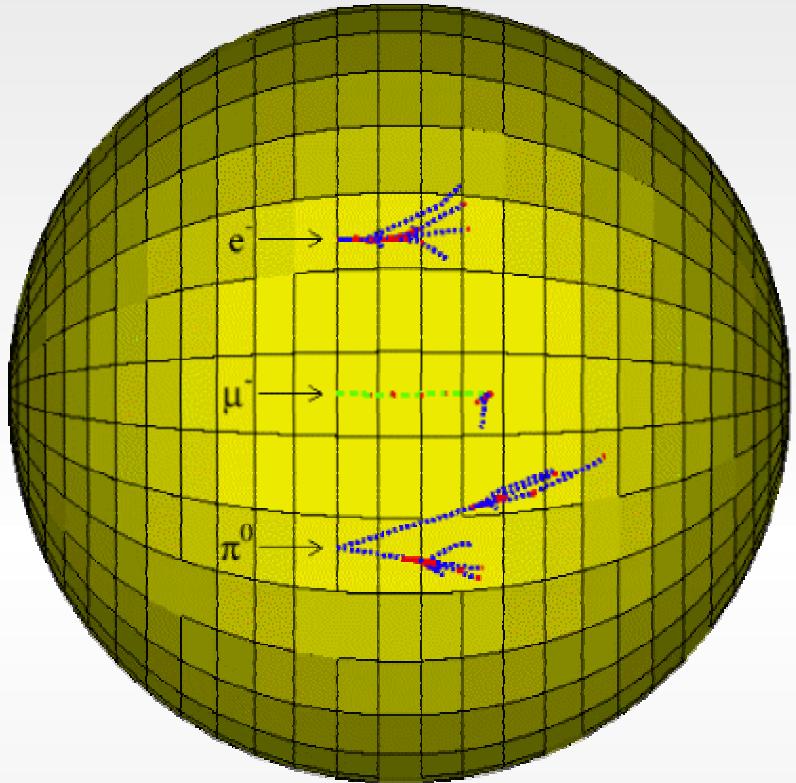


- Veto region (240 PMTs)
- Primary DAQ electronics: some new, most recycled from LSND
- All new DAQ software
- Muon tracker for cosmic rays

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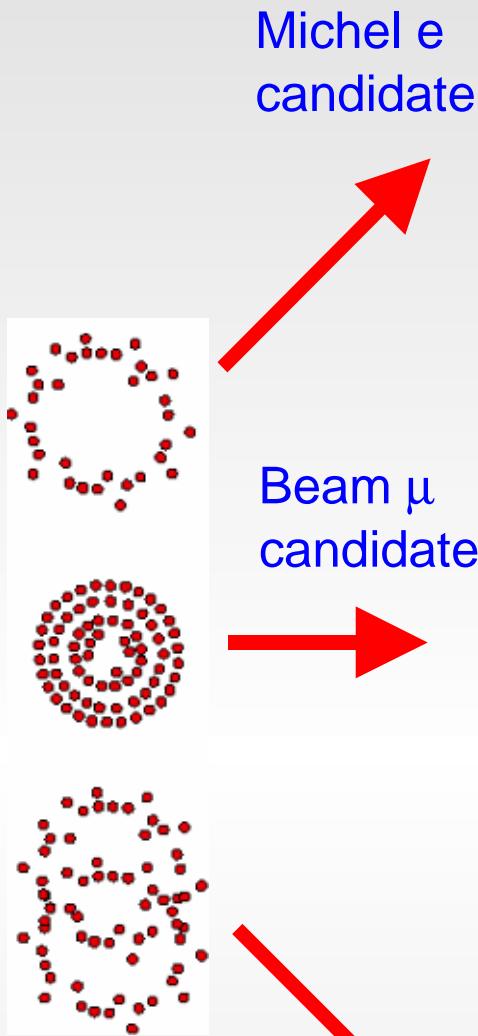
Particle ID



- Identify electrons (and thus candidate ν_e events) from characteristic hit topology

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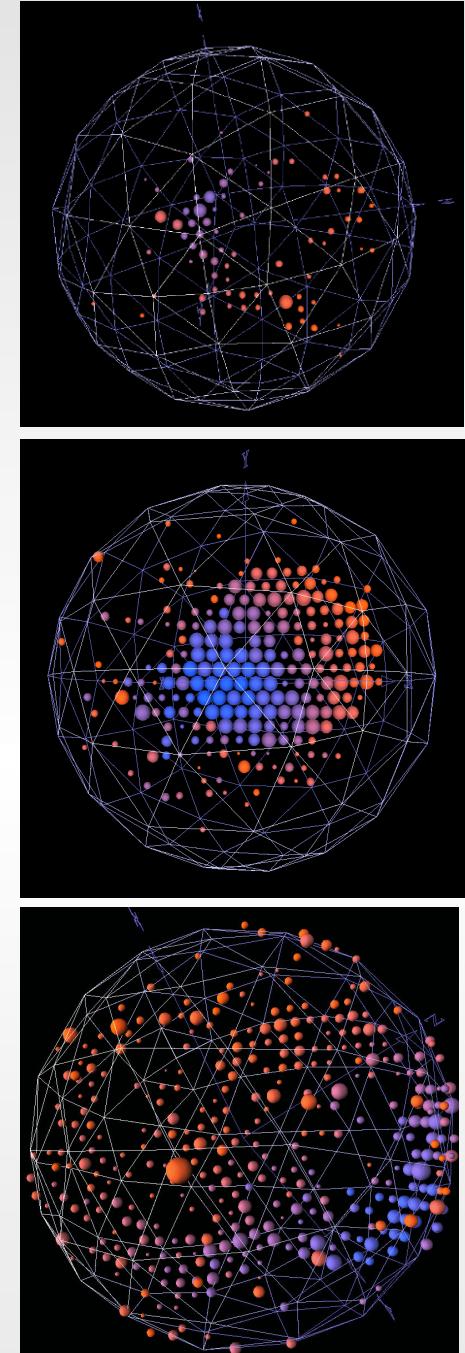
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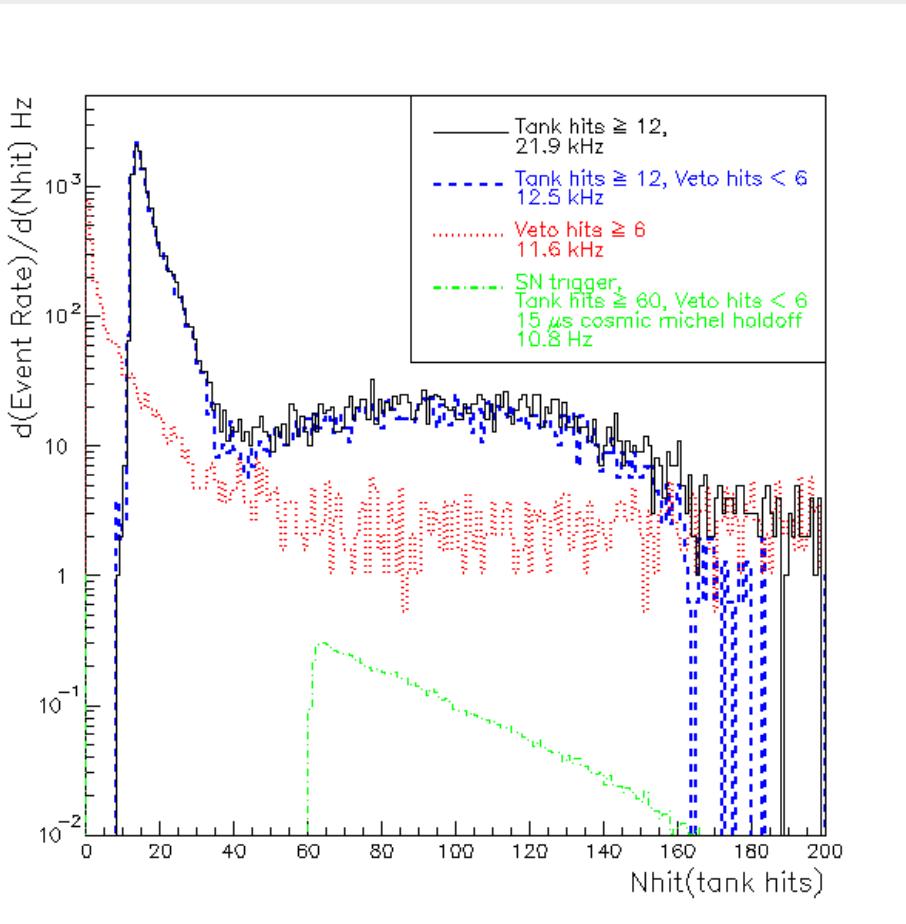
Michel e
candidate

Beam μ
candidate

Beam π^0
candidate

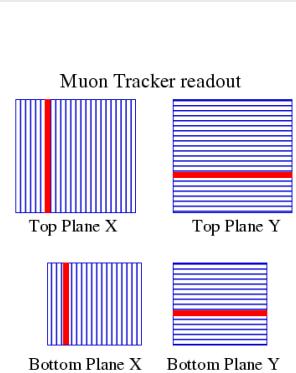
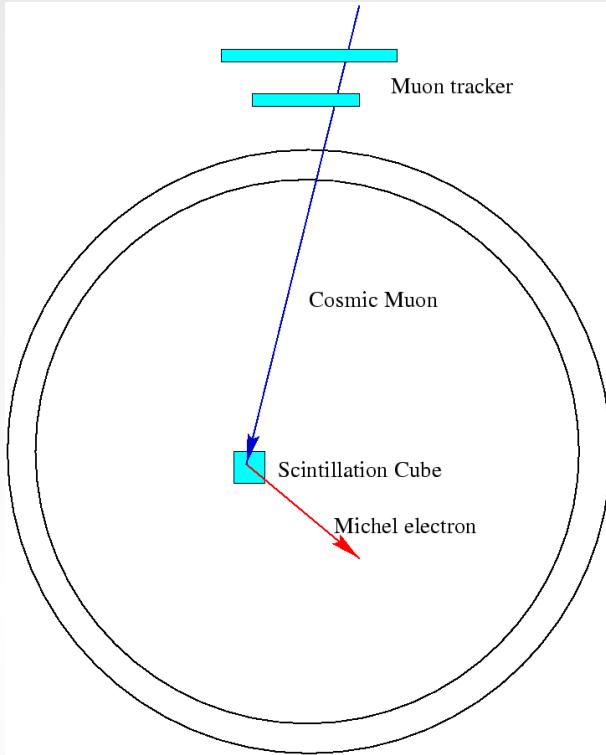


Data sources

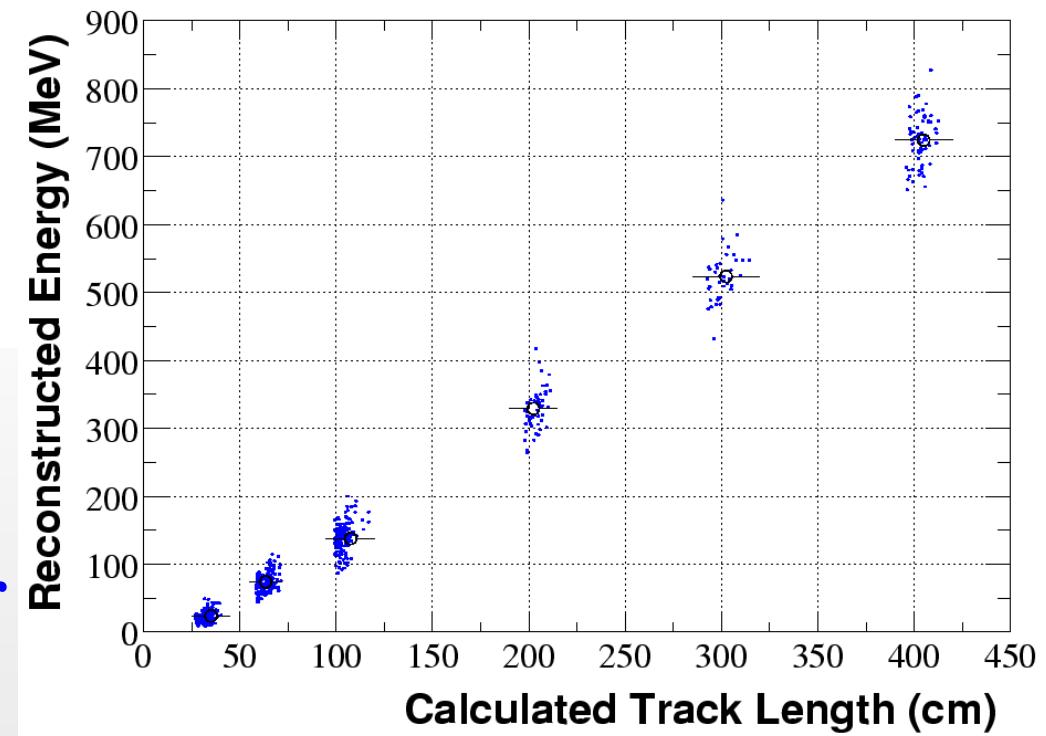


- **Tank DAQ**
 - Beam neutrinos (~3 Hz)
 - Pulser triggers (~2 Hz)
 - Laser calibration (~1.5 Hz)
 - External non-beam events (~15 Hz)
- **Accelerator Control NETwork**
 - Detailed beam info
 - Some slow monitoring
- **Resistive Wall Monitor**
 - Detailed beam timing
- **Little Muon Counter**
 - Kaon production info

Calibration tools



Position resolution and Michel characteristics studied with Muon Tracker and 7 scintillator cubes

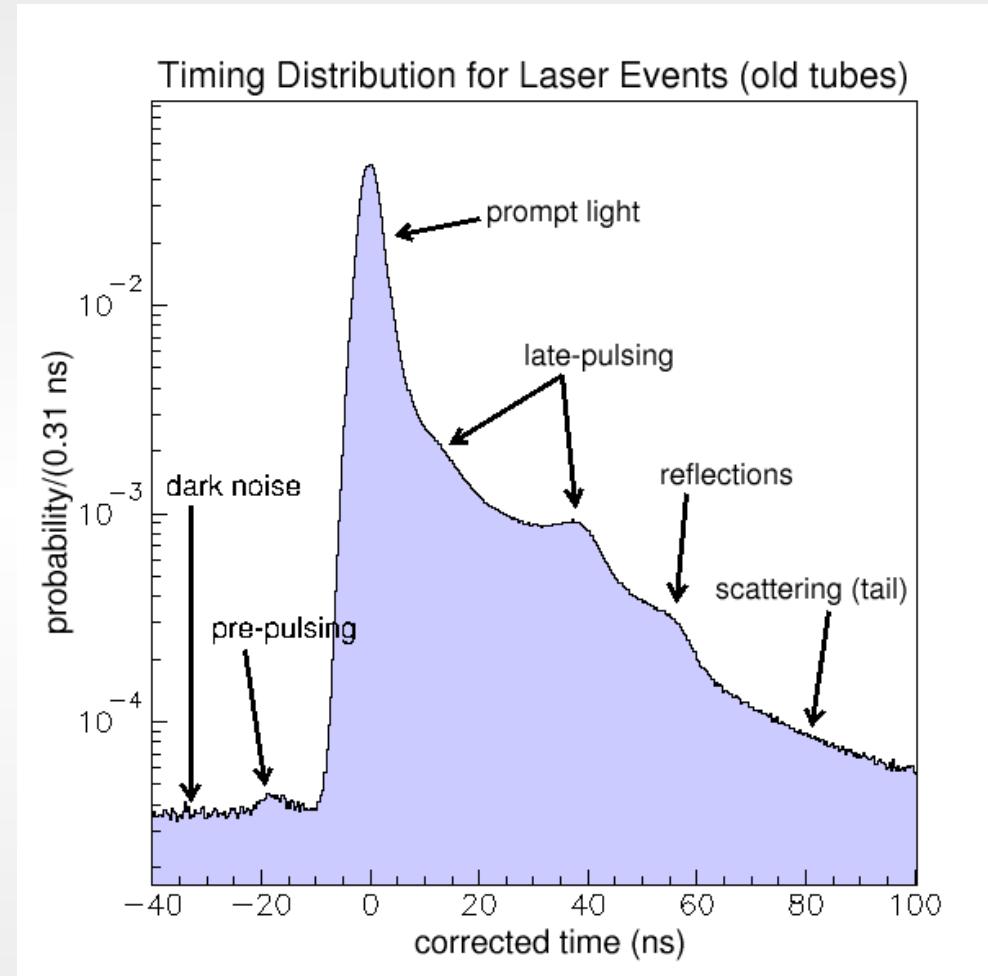


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Calibration tools

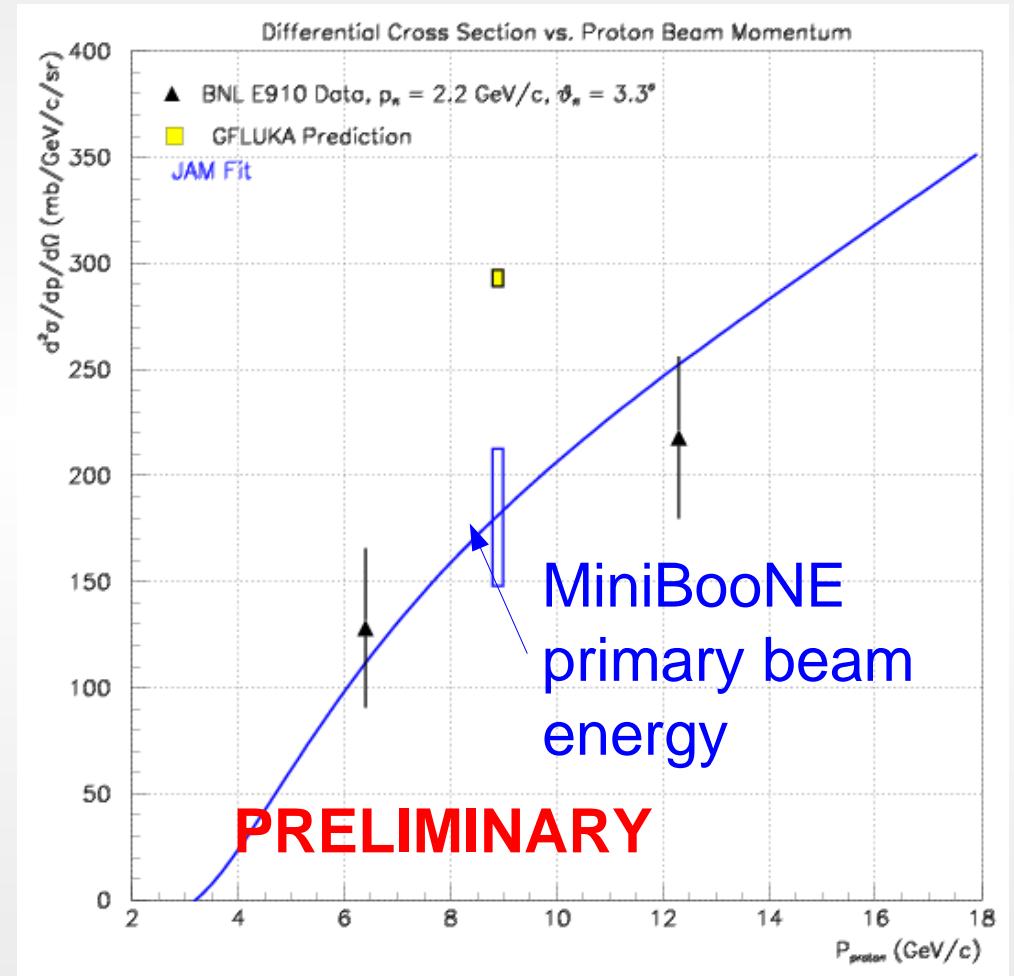
PMT charges and times
calibrated with laser
routed to one of 4 Ludox
flasks



Modelling the flux

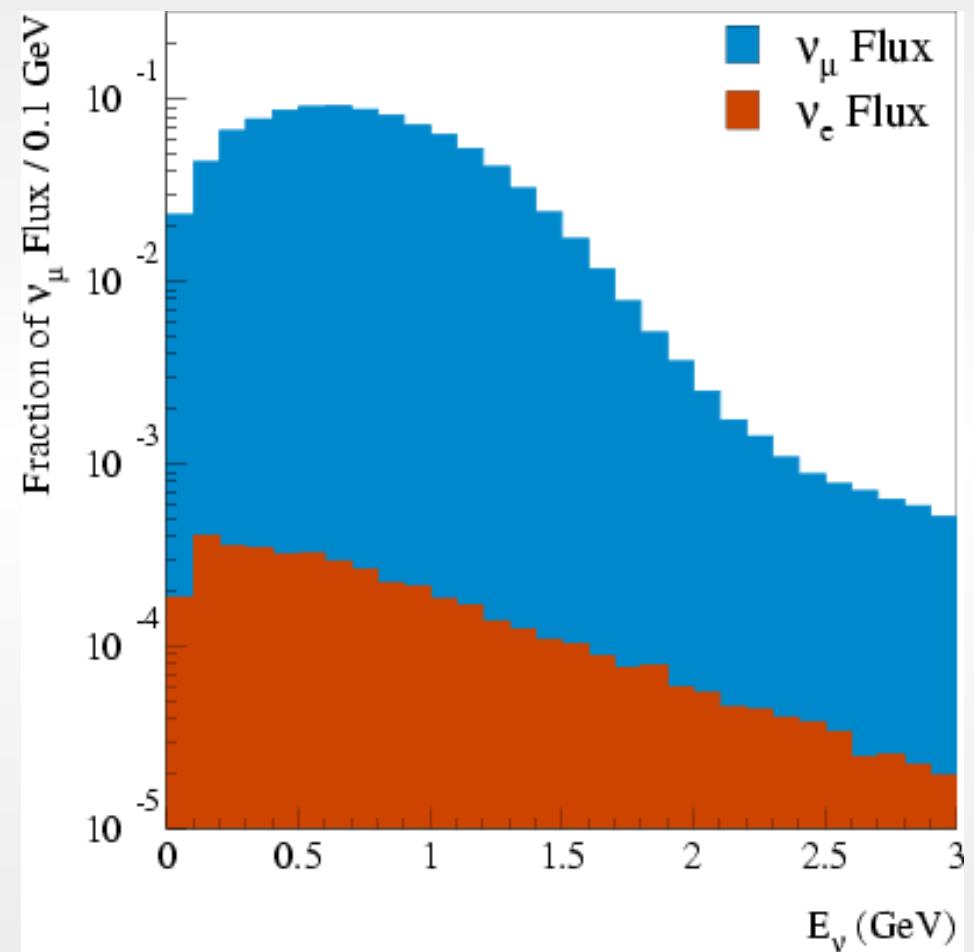
$$\frac{d^2 \sigma}{dp d\Omega} = W_1 p_\pi^{W_2} \left(1 - \frac{p_\pi}{p_{proton}}\right) \times \exp\left(\frac{-W_3 p_\pi^{W_4}}{p_{proton}^{W_5}} - W_6 \theta_\pi (p_\pi - W_7 p_{proton} \cos^{W_8} \theta_\pi)\right)$$

- Need "modern" Sanford Wang fit to relevant low-energy data
- Use Be target data from:
 - BNL: E910
 - CERN: HARP (in progress)



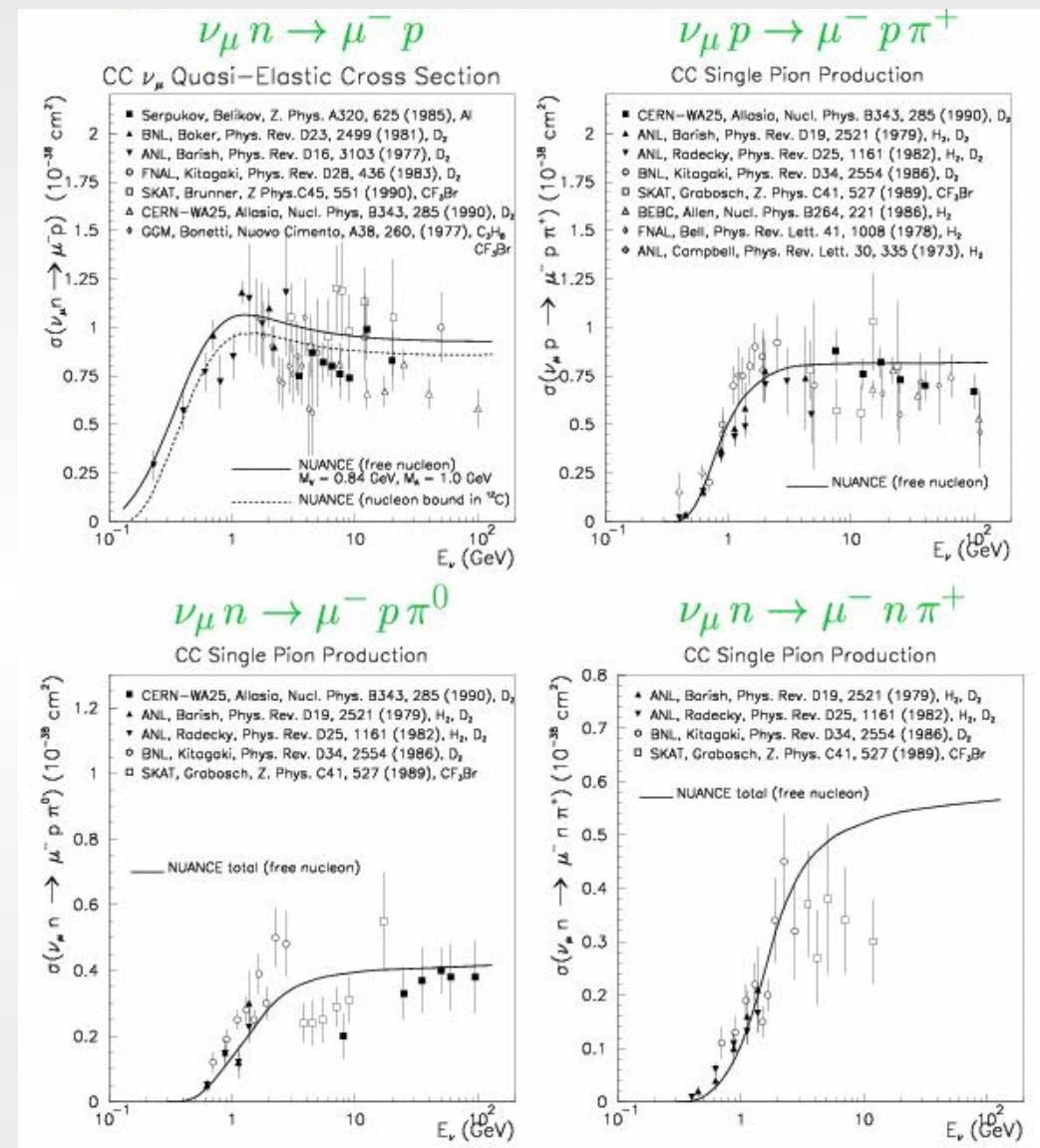
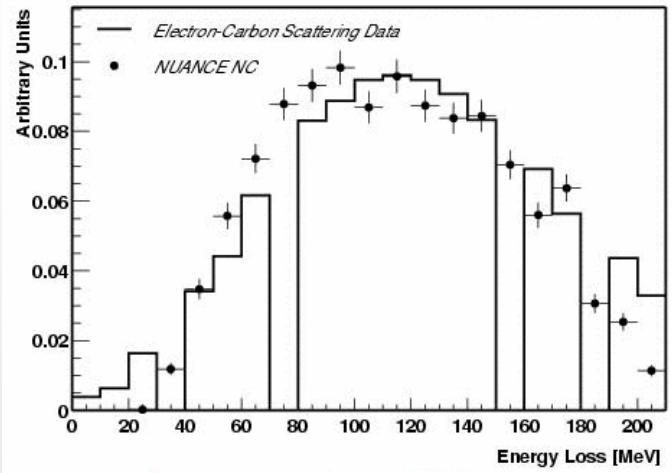
Modelling the flux

- Beam simulated using Geant 4, with meson production models from external sources:
 - MARS (kaons)
 - Sanford-Wang fits (pions)



Modelling cross-sections

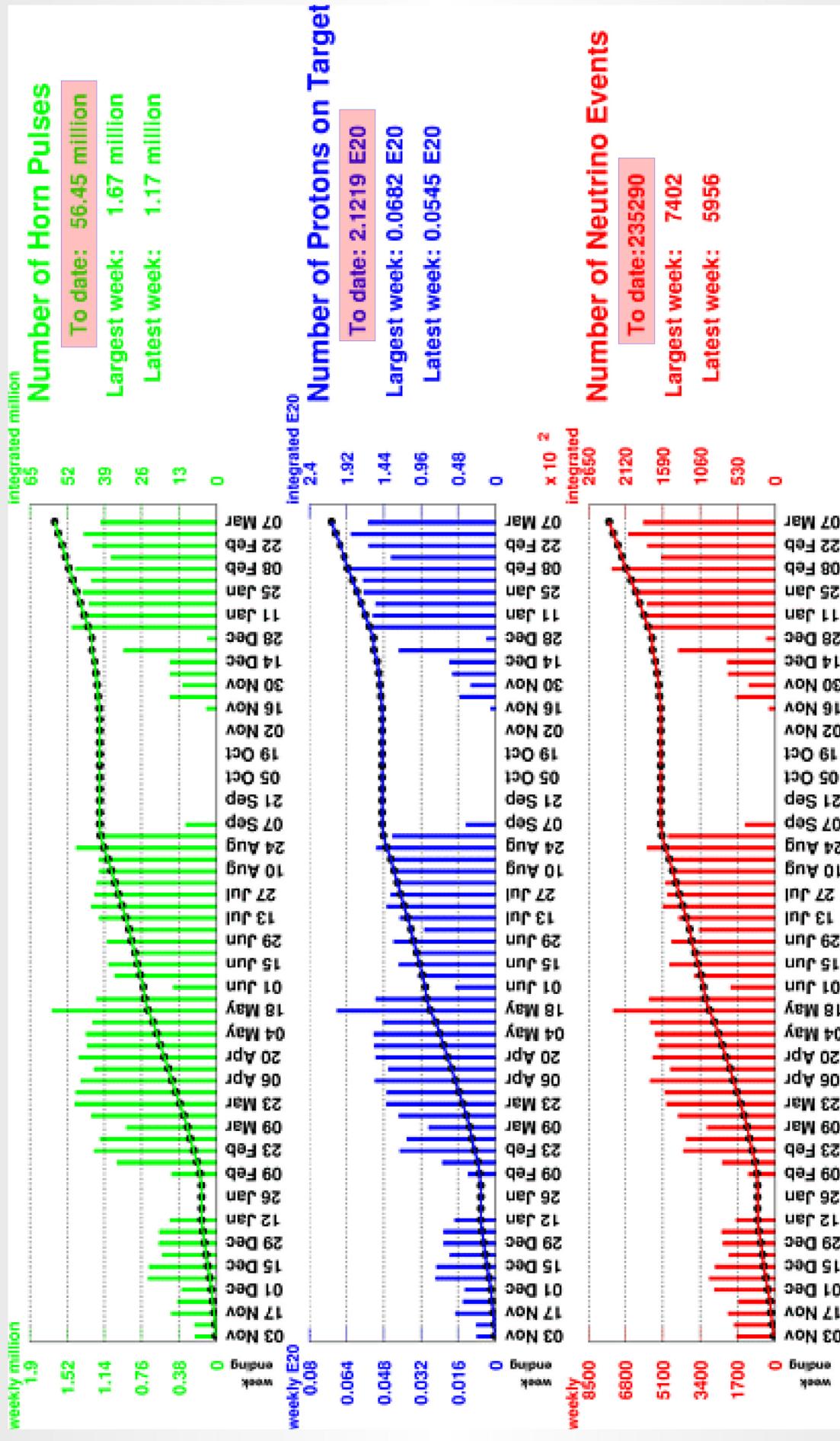
- Several Monte Carlos in use:
 - Nuance v2 (MiniBooNE default up to now)
 - Nuance v3 (new)
 - Neugen (H. Gallagher, Minos)
 - NEUT (Y. Hayato, K2K)



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Current status



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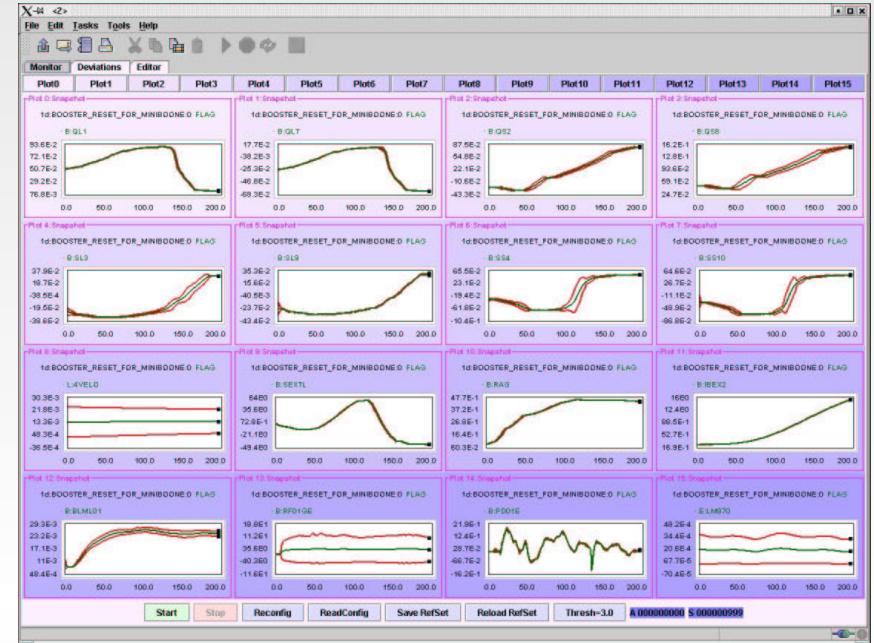
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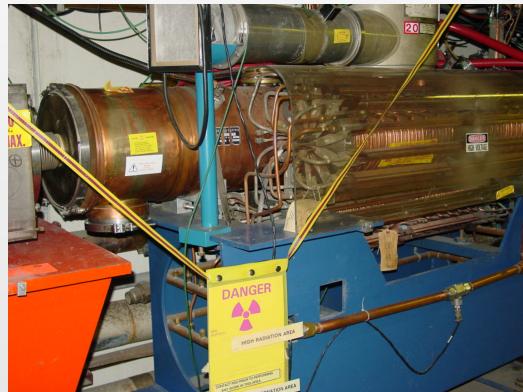


Contributions to Booster

- Larger RF cavities
- Ramp monitoring code and studies
- Loss calculations and studies
- TLM hardware construction
- Dipole corrector electronics and software
- Neutron transport MC
- General Booster studies



»>2 person-years of postdoc level, with additional contributions from professors, graduate and undergraduate students!

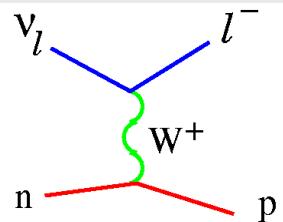


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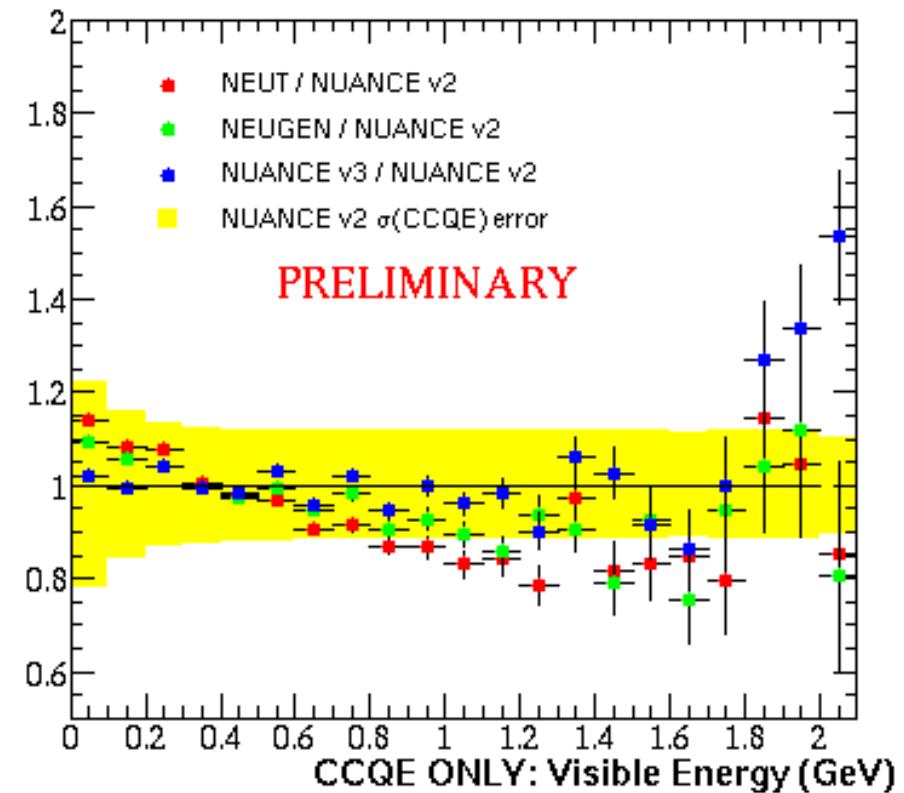
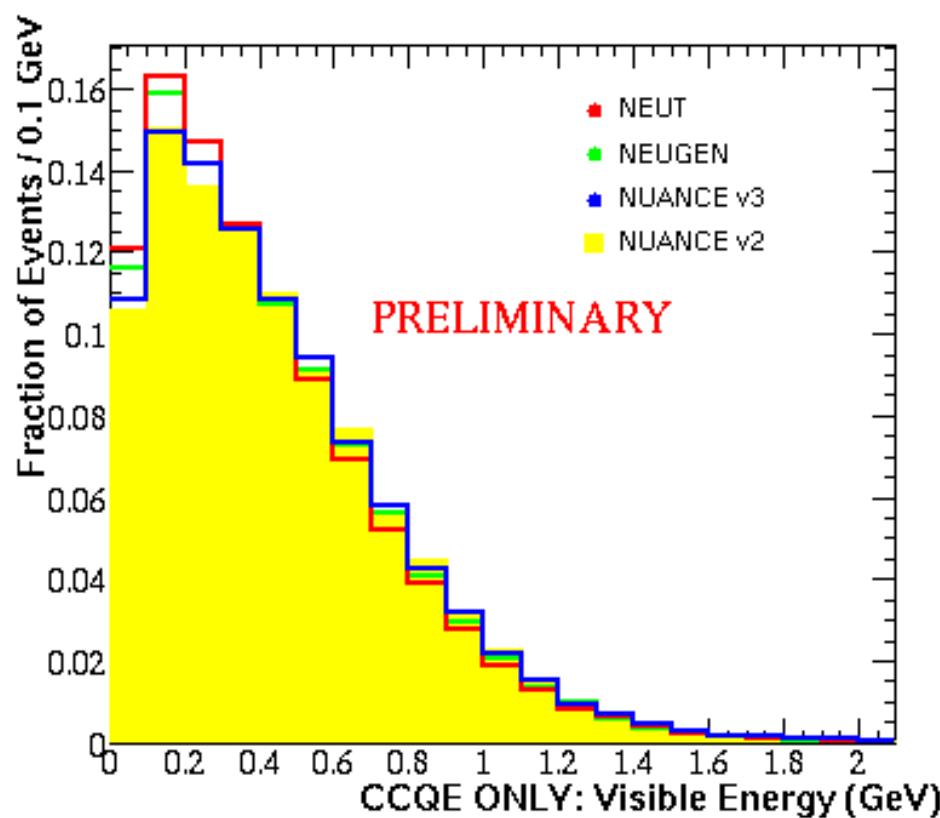
Real Data!

- >200K neutrino events to date, with lots of calibration data
- Three main thrusts so far:
 - Charged current quasi-elastic events
 - Neutral current resonant & coherent π^0 events
 - Neutral current elastic events
- Comparisons now possible (new!) with multiple MCs.

Charged current QE studies

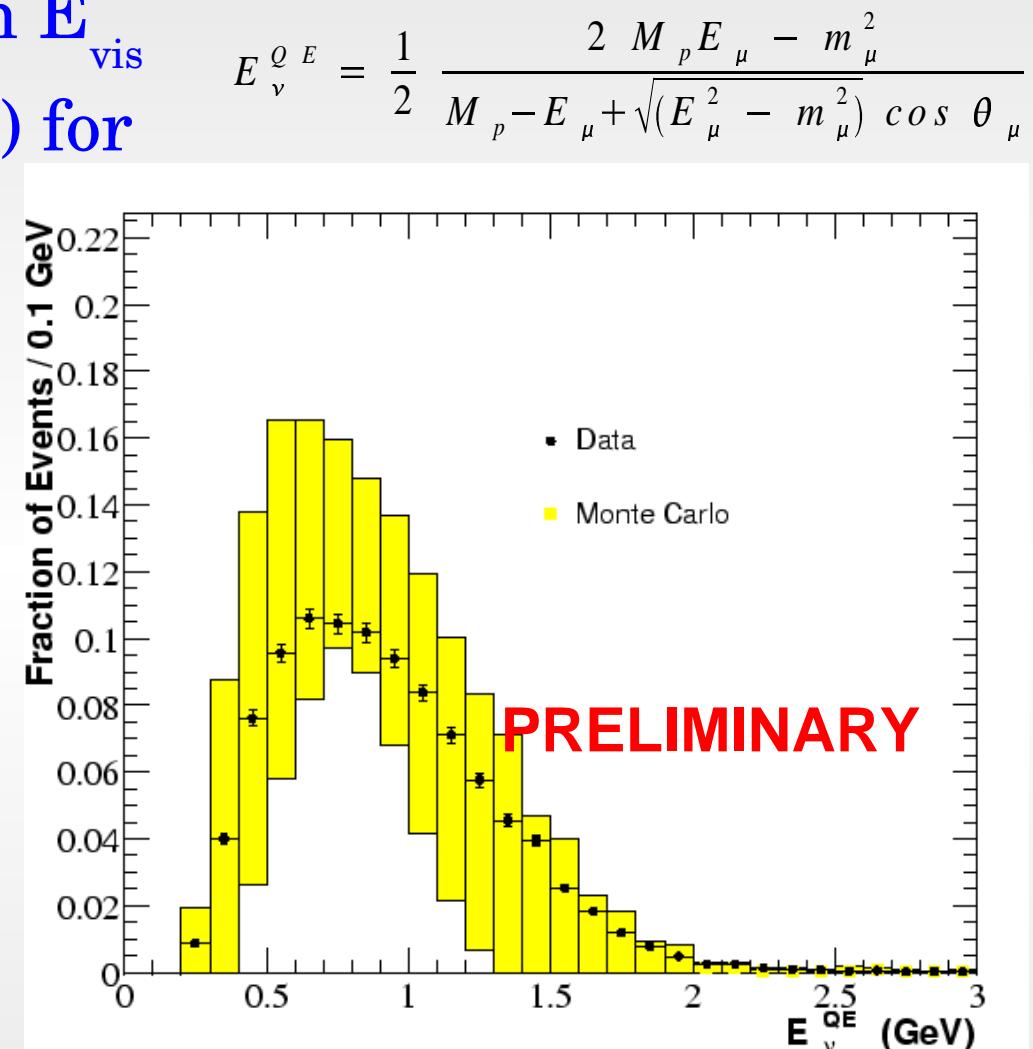
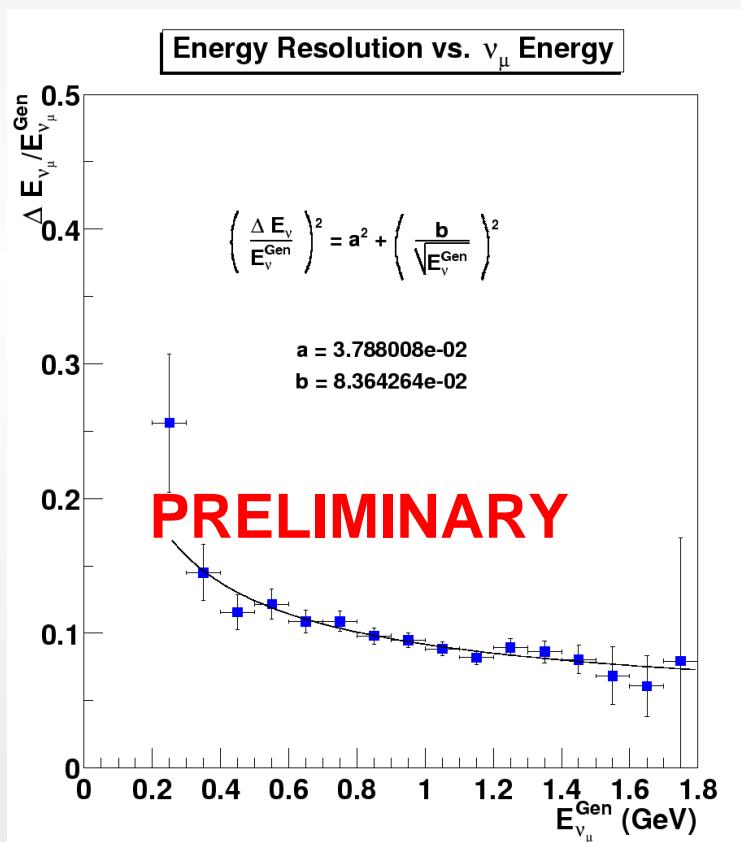


- Understanding of signal and relevant backgrounds essential for ν_μ disappearance!



Charged current QE studies

- Need to reconstruct E_{ν} from E_{vis} (Cerenkov and scintillation) for muon events

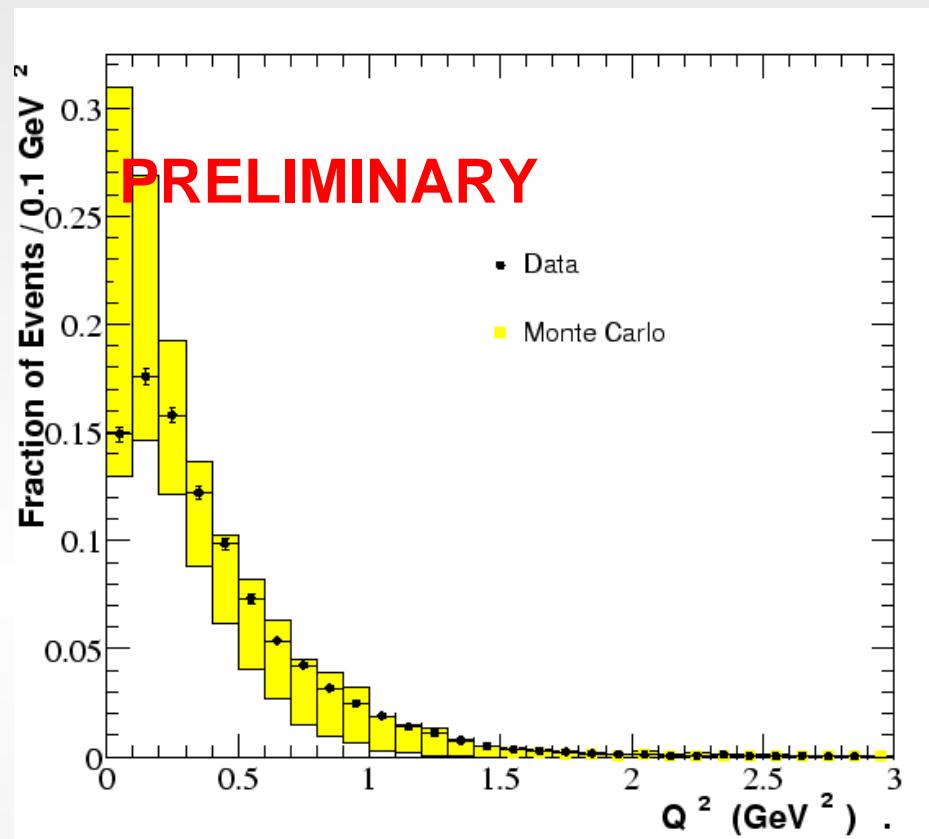
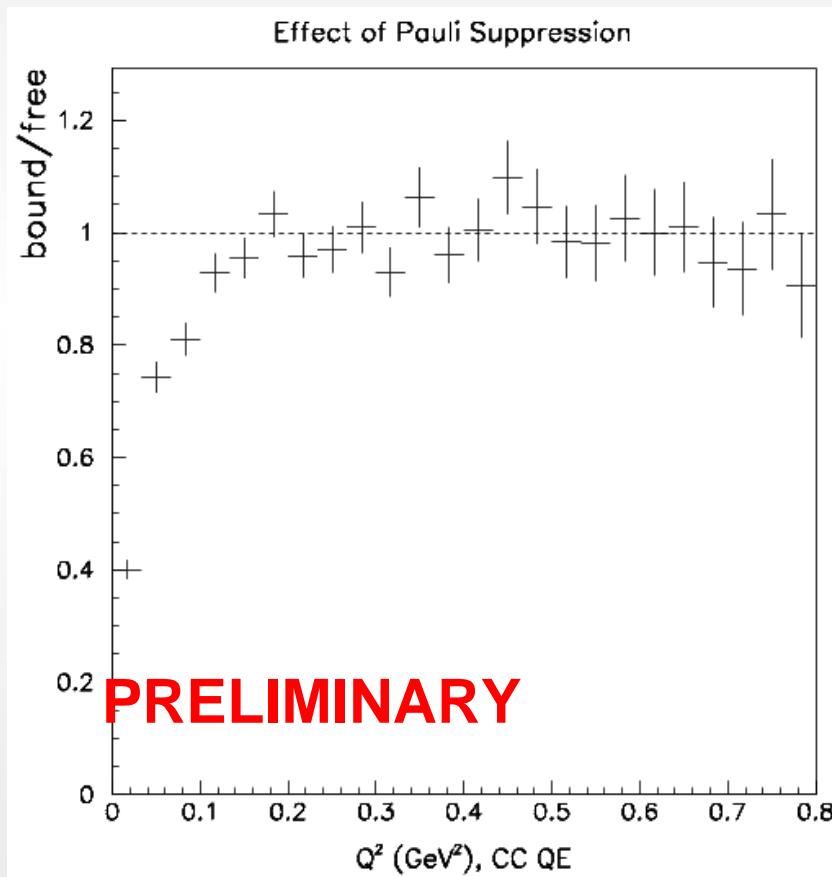


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Charged current QE studies

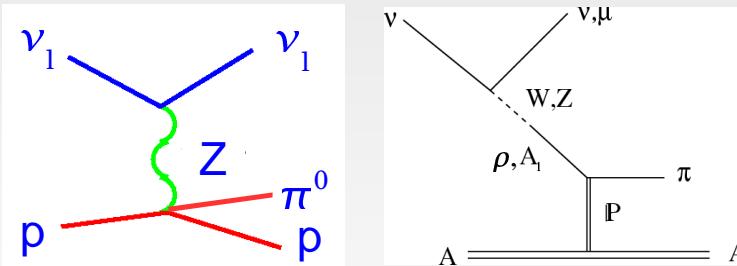
$$Q^2 = 2E_\nu E_\mu (1 - \beta_\mu \cos \theta_\mu) - m_\mu^2$$



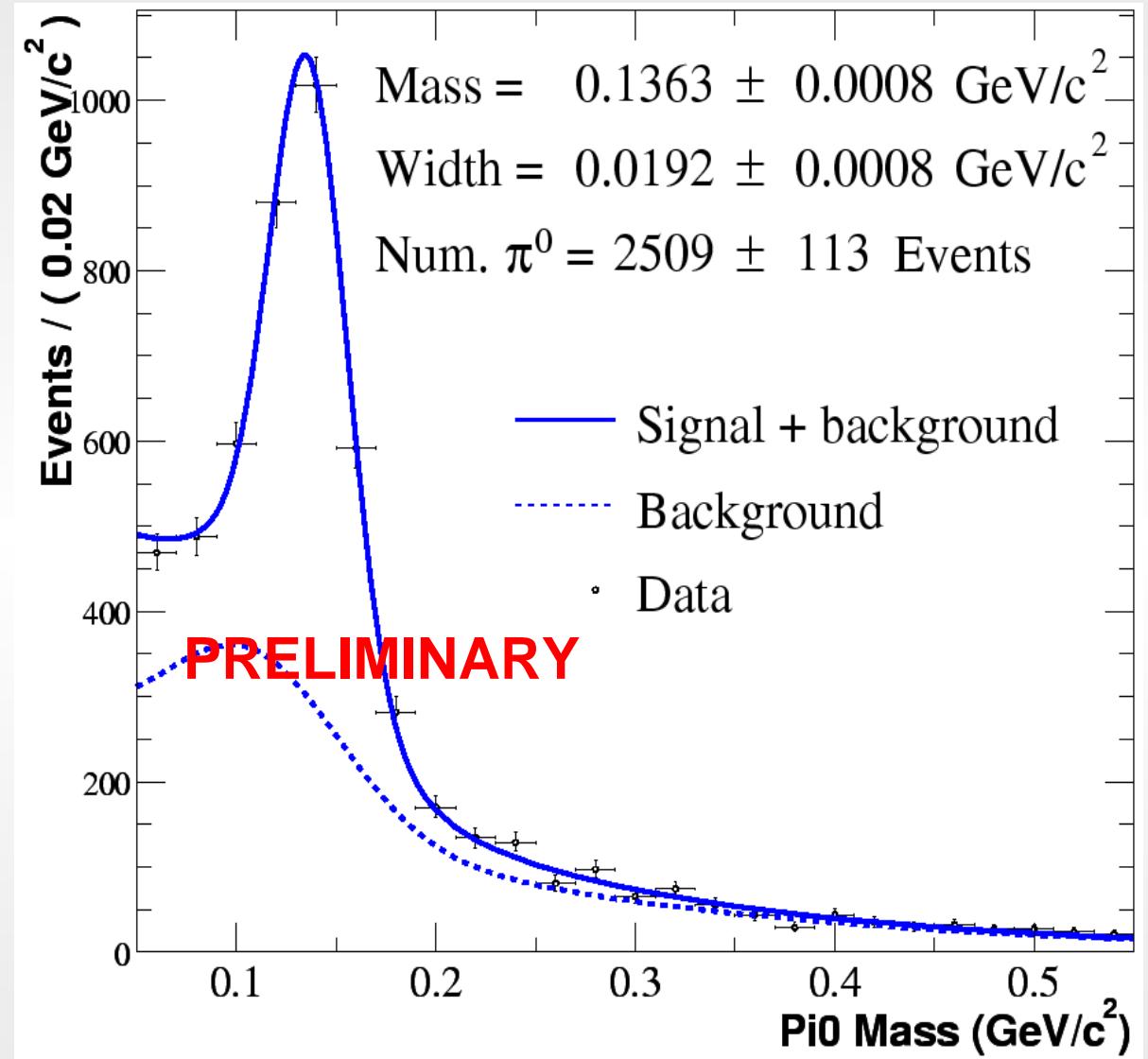
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Neutral Current π^0 events

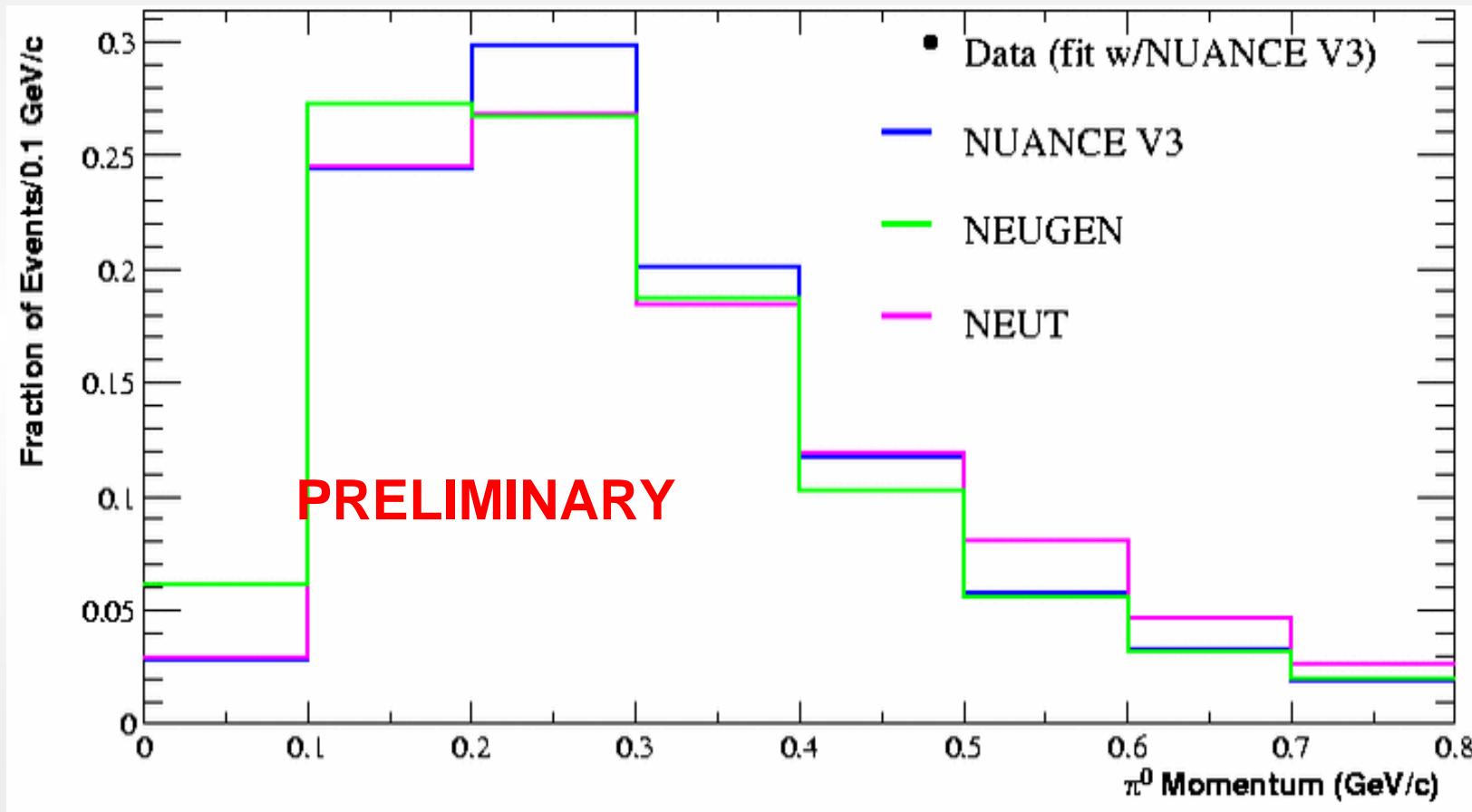


- Important background to oscillation search

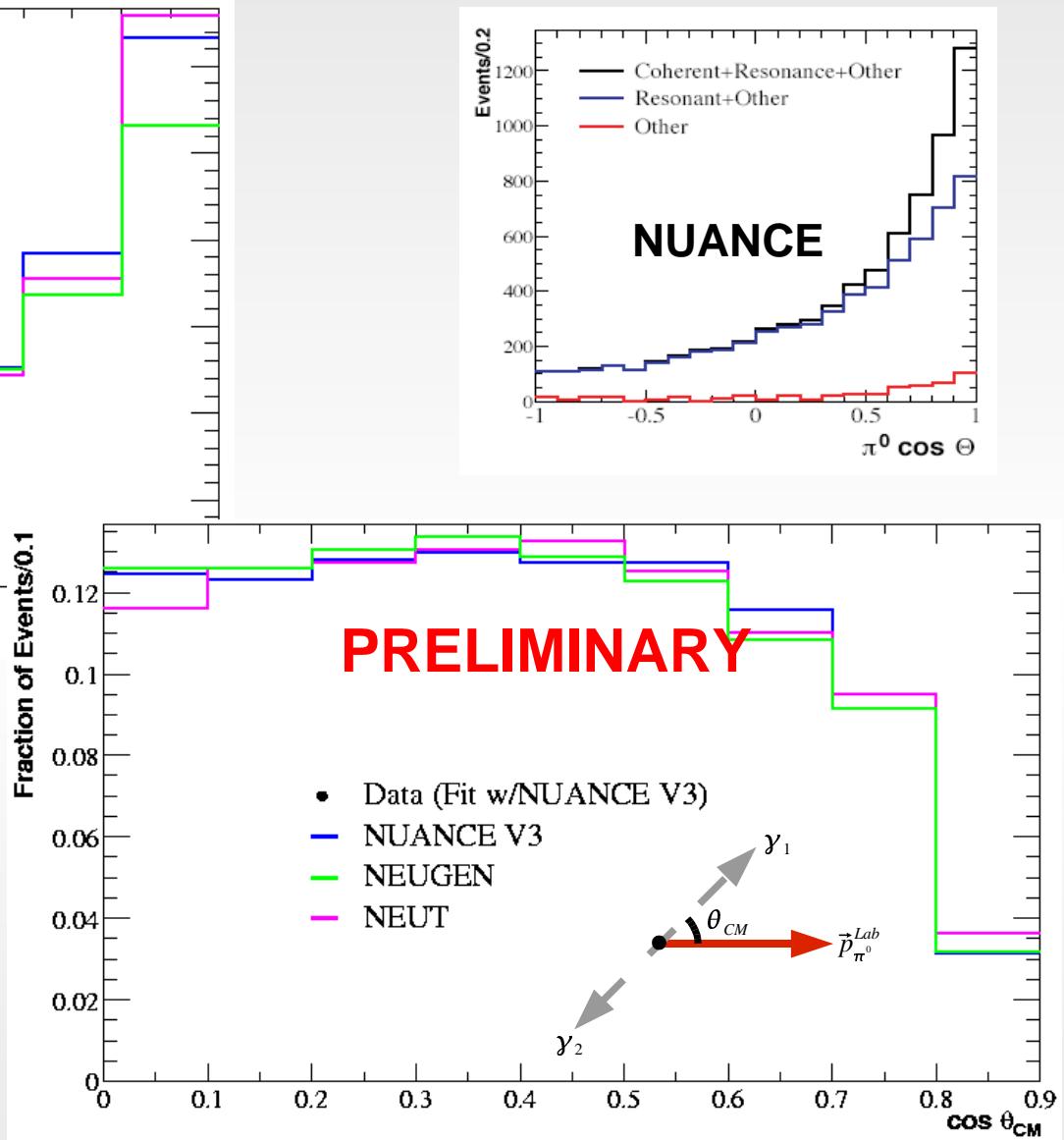
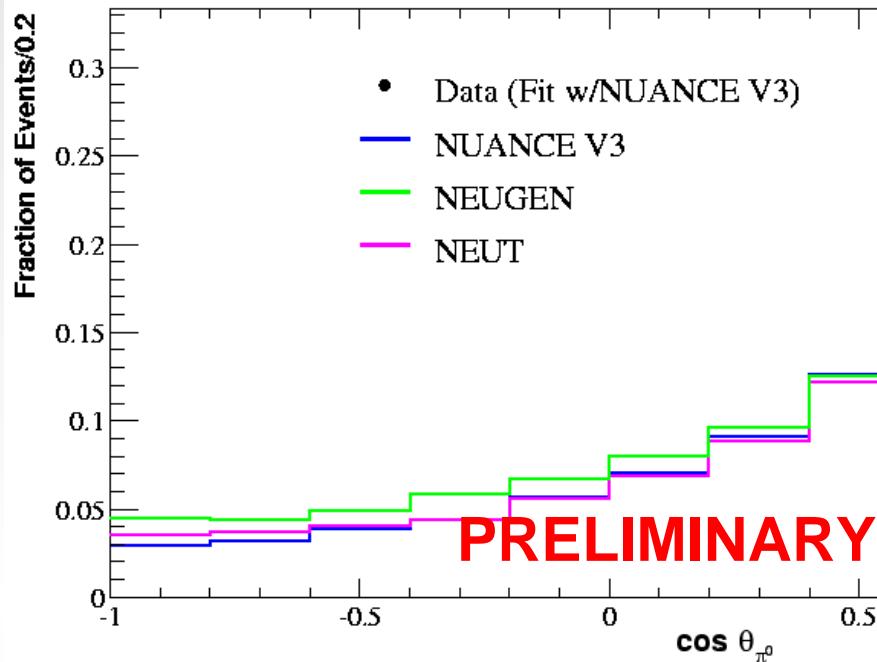


Neutral Current π^0 events

- Very good MC-data agreement!



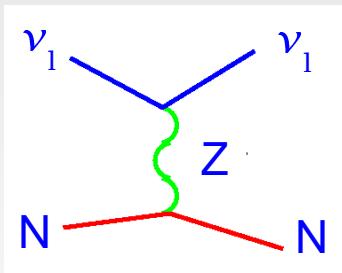
Neutral Current π^0 events



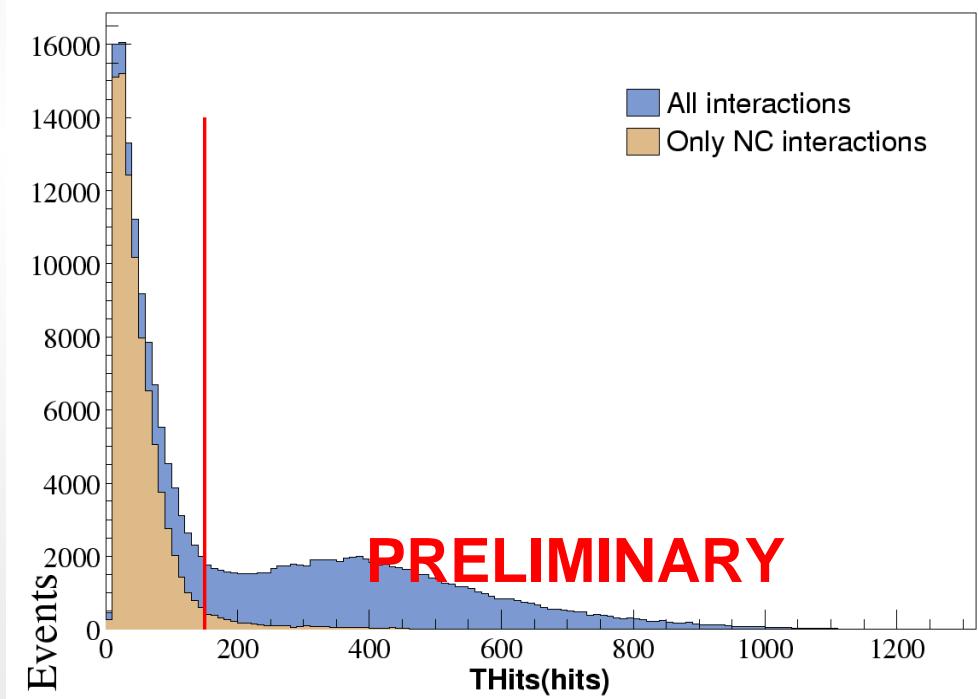
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Neutral current elastic events



- What carries the proton spin: valence quarks, sea quarks or gluons?
- $\sigma(\text{NCE})/\sigma(\text{CCQE})$ ratio probes strange sea contribution to nucleon spin
- Useful for studying scintillation light for oscillation search

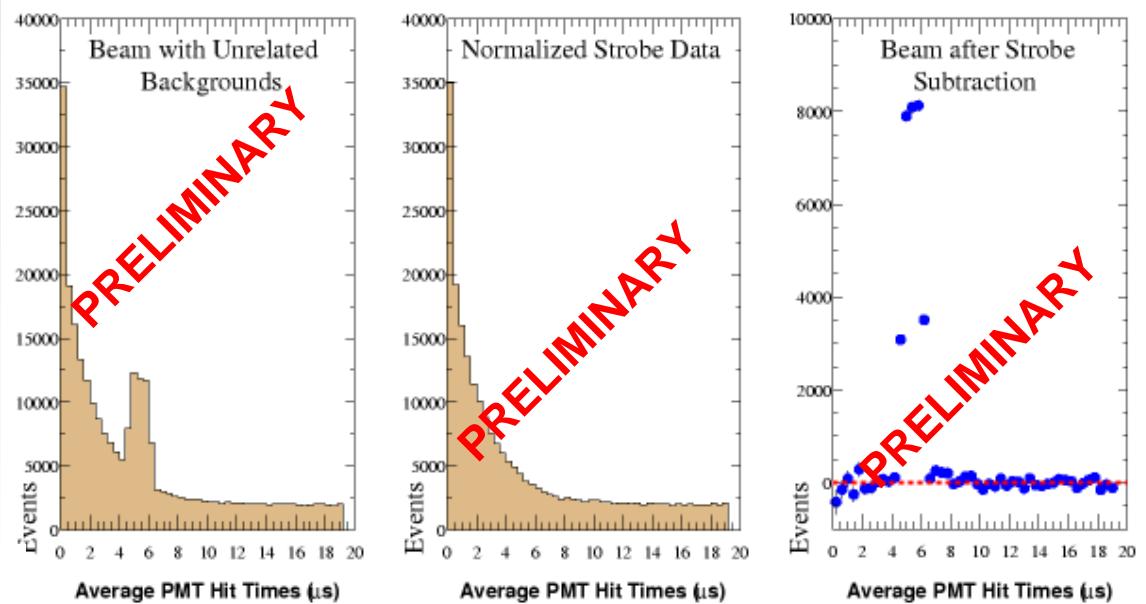
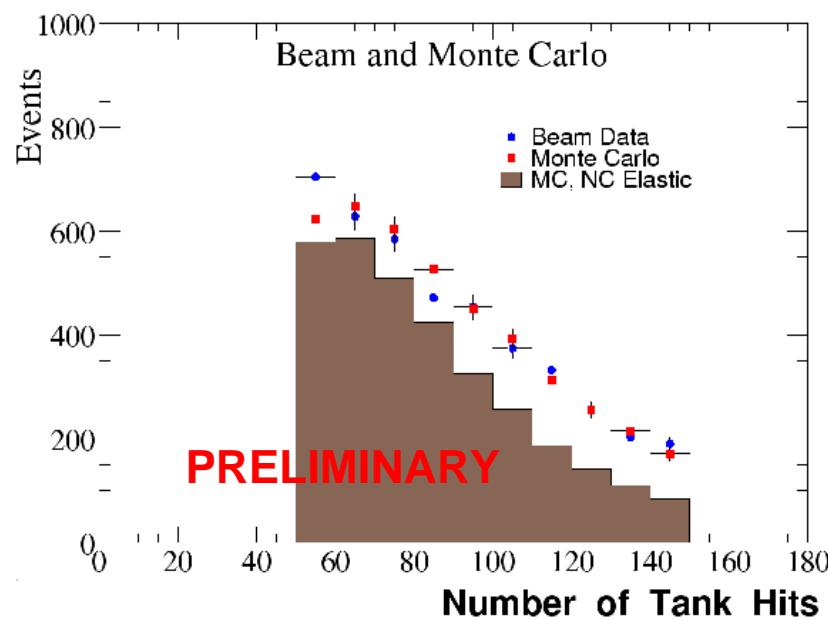


- Typically sub- : dominated by scintillation
- Low hit multiplicity, large scintillation fraction
- Large cross section (~17%)

Neutral current elastic events

Subtract background:

- Beam excess clearly visible for <150 hits
- Non-beam background from decay electrons, environmental activity



Event selection:

- $50 < N_{TANK} < 150$
- Scintillation light $> 50\%$
- Reasonable agreement between MC and data.

Conclusions

- Beam data coming in: continued improvements to booster intensity and reliability
- Rapid progress understanding our data and refining reconstruction and analysis: on track for "flagship" analysis result in 2005
- Need 1×10^{21} POT to confirm or rule out LSND definitively!
- Other analyses promise to increase world understanding of neutrino-nucleon interactions.